

Parijs 1971

ORSAY
Série A
N° d'Ordre : 851

Sujet de la Thèse :

Mesure du rapport $|\eta_{00}|e^{i\phi_{00}}$ des amplitudes de désintégration du K_L^0 et du K_S^0 dans le mode $2\pi^0$, du rapport de branchement du K_L^0 en 2γ et d'une limite supérieure du rapport de branchement du K_S^0 en 2γ .

ARTICLE PRINCIPAL :

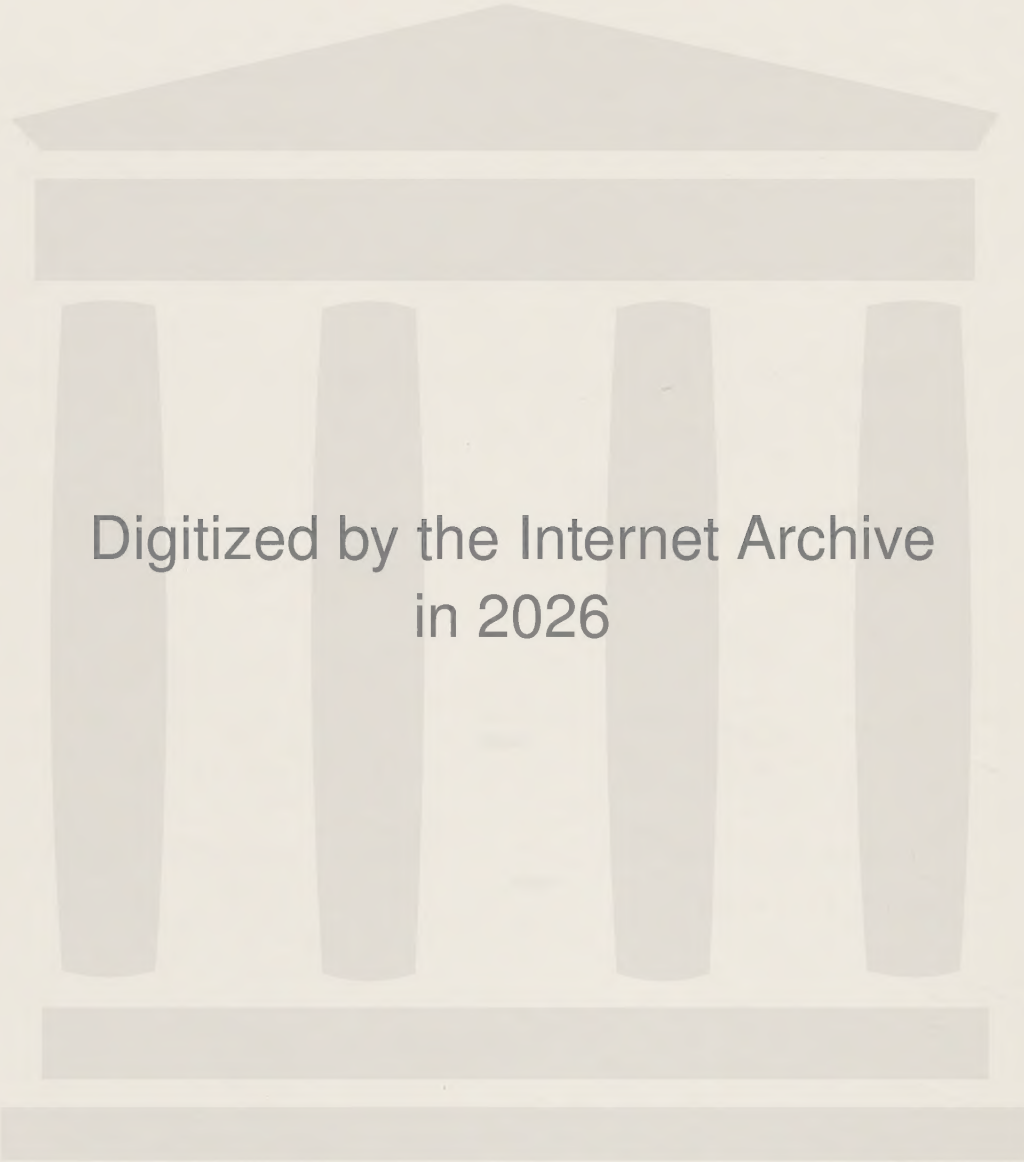
FURTHER RESULTS ON THE INTERFERENCE BETWEEN THE $\pi^0\pi^0$ DECAY OF K_L^0
AND K_S^0 .

recouvrant en partie le thèse de Doctorat ès Sciences
enregistrée au C.N.R.S. sous le numéro A.O. 6207

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Soutenue le 21 Octobre 1971 à la FACULTE DES SCIENCES D'ORSAY,
devant le jury :

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FURTHER RESULTS ON THE INTERFERENCE BETWEEN
THE $\pi^0\pi^0$ DECAY OF K_L^0 AND K_S^0

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ABSTRACT

The experiment of Chollet et al¹⁾ has been continued with a similar set up. The analysis of these new data leads to 56 free decay events $K_L^0 \rightarrow \pi^0\pi^0$ and 1481 interference events $K_{S,L}^0 \rightarrow \pi^0\pi^0$ behind a 20 cm thick copper regenerator. The results are $\varphi_{00} = 38^\circ \pm 25^\circ$ and $|\eta_{00}| / \frac{|f-\bar{f}|}{k} = (1.13 \pm 0.12) \times 10^{-3}$ where $\frac{|f-\bar{f}|}{k}$ is the regeneration amplitude for copper at 2 GeV/c in fm².

Geneva - July 1971
(Submitted to Physics Letters)

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Data have been taken in a 17° neutral beam derived from a tungsten target placed in the external proton beam at the CERN PS. The apparatus, very similar to the one of reference 1, is shown in Figure 1. The experiment aimed to measure the modulus and the phase of $\eta_{00} = A(K_L^0 \rightarrow 2\pi^0) / A(K_S^0 \rightarrow 2\pi^0)$. The trigger required four gammas converted in the aluminium spark chamber modules. 170'000 photographs were taken with a 20 cm thick copper regenerator in position M (Main Regenerator), 70'000 with the same regenerator in six different positions between I and J (Internal Regenerator), and 125'000 without regenerator (Free Decay). The length of the detection region, from M to J was 1.25 meters. The momentum of the detected K^0 's was spread over the range 1.5 to 3.5 GeV/c, corresponding to a mean momentum of 2.2 GeV/c. The scanning criteria were similar but somewhat tighter than in the previous experiment¹⁾. The analysis was made assuming that the four gamma rays originated from the decay of two neutral pions, and the selection criteria were similar but somewhat tighter than those of reference 1 in order to improve the signal to background ratio²⁾. The mass distributions obtained are shown in Figure 2a for the Main Regenerator data, and in Figure 2b for the Free Decay data.

The number of measured four gamma ray events has been used as an internal monitor between the different sets of data. When selected for invariant masses outside the K^0 mass region, those four gamma events are almost completely due to $K^0 \rightarrow 3\pi^0$ decays, where two gammas have escaped detection. The rates of different external monitors were permanently recorded during the runs, as well as the deadtime of the various anticoincidence counters. This deadtime was approximately 20% for the regenerator runs and 10% for the free decay runs. A careful study of the behaviour of the different monitors as a function of the deadtime has shown that the internal monitor gave a reliable measurement of the K^0 flux for each condition²⁾.

In the regenerator case, the internal monitor events arise from three contributions: transmission, diffraction and inelastic scattering of K_L^0 , whereas in the free decay case only the transmission contributes. A detailed study of the different terms has been made by comparing the vertex distribution of the events along the beam direction (Z) for the free decay data and for the regenerator data; the same problem has also been investigated by Monte Carlo simulation (MC) of $3\pi^0$ decays. The ratio diffracted/transmitted is 44% near the regenerator and reduces to 23% at 60 cm from the chamber front. This reduction is due to a lower triggering efficiency for the off axis K^0 decays and to the selection criteria on the transverse coordinates (X' , Y') of the decay point. The inelastic contribution is important near the regenerator but decreases rapidly along the Z axis towards the chambers. On the basis of this study the ratio between transmitted K^0 fluxes for regenerator and free decay data was determined to be 0.290 ± 0.008 , where the error is statistical only.

The curves drawn in figure 2a and 2b are the background distributions deduced from the $3\pi^0$ MC, applying the same criteria used for the selection of the data. In Figure 2b there are 56 signal events and 36 background events in the K^0 mass interval ($460 \text{ Mev}/c^2 - 540 \text{ Mev}/c^2$). The relative background level between regenerator and free decay was determined by using the ratio between internal monitors. The absolute level has been established by normalizing the MC to the data outside the K^0 mass interval using wider selection criteria corresponding to higher background levels. There is good agreement between the MC and the data over the whole range of criteria used.

To study the $K_{S,L}^0$ interference in the regenerator events, an apparent time $\tau' = Z' / 5.2 p'$ was defined; Z' is the coordinate of the decay vertex relative to the exit face of the regenerator, p' is the reconstructed momentum of the K^0 . The $2\pi^0$ decay

intensity including scattering effects is given by:

$$\begin{aligned}
 I_{\pi^0\pi^0} \sim & |\eta_{00}|^2 \sum_{n=0}^{\infty} \epsilon_n \frac{(NL\sigma_D)^n}{n!} \\
 + & |\rho|^2 e^{-Z/\Lambda_S} \left[\sum_{n=0}^{\infty} \epsilon_n \frac{(NL\sigma_D)^n}{n!} \left\{ 1 + \frac{4n\psi}{(NL\sigma_T)^2} - \frac{4n}{NL\sigma_T} + \frac{4n(n-1)}{(NL\sigma_T)^2} \right\} \right] \\
 & + 2|\rho||\eta_{00}| e^{-Z/2\Lambda_S} \times \\
 & \times \left[\sum_{n=0}^{\infty} \epsilon_n \frac{(NL\sigma_D)^n}{n!} \left\{ \cos(\delta Z/\Lambda_S + \varphi_\rho - \varphi_{00}) - \right. \right. \\
 & \left. \left. - \frac{2n}{NL\sigma_T} \cos(\delta Z/\Lambda_S + \varphi_\rho - \varphi_{00} - \varphi_{22}) \right\} \right] \quad (1)
 \end{aligned}$$

The definitions of the parameters used in the above formula have been given in reference 1. Values of $\sigma_D = 228$ mb, $\sigma_T = 960$ mb, $\phi_{22} = 8^\circ$ and $\delta = 0.469$ have been used. The K^0 momentum spectrum has been measured by Böhm et al³⁾ for the same production angle. Integrating formula 1 over Z and p leads to the expected τ' distribution as a function of $\phi_{00} - \phi_f$ and $|\eta_{00}/\rho|$ provided the efficiencies are known. The relative efficiencies along the beam direction have been studied using the MC and the internal regenerator data. There is good agreement between the MC and the data with the exception of the Z region near the chamber front, where small corrections have been introduced. The internal regenerator data have also been used to study the vertex shift effects.

To determine $|\eta_{00}|$ from the data, one needs the value of the regeneration amplitude $|f - \bar{f}|/k$ for copper around 2 GeV/c. We believe that there is not yet a reliable measurement of this parameter⁴⁾; therefore the fit has been made as a function of the two parameters $\phi_{00} - \phi_f$ and $|\eta_{00}| / (|f - \bar{f}|/k)$. The Main Regenerator events were grouped into τ' intervals of width $\tau_s/2$. For the mass region $460 \text{ MeV}/c^2 - 540 \text{ MeV}/c^2$ the τ' distribution and the number of free decay events have been fitted to the expected $2\pi^0$ plus background distribution.

The results of the maximum likelihood fit are:

$$\varphi_{00} - \varphi_f = 86^\circ \pm 21^\circ; |\eta_{00}|/(|f-\bar{f}|/k) = (1.13 \pm 0.09) \cdot 10^{-3}$$

Measurements obtained with a copper regenerator give an average value⁵⁾ of

$$\varphi_f = -48.2^\circ \pm 3.5^\circ$$

Figure 3a shows the decay time distribution of the regenerator data with the maximum likelihood fit. Figure 3b gives the likelihood contours for 1, 2, 3 standard deviations from the central value.

Possible systematic effects have been studied and table 1 gives a list of corresponding errors. Including systematic effects, the results of this analysis is:

$$\varphi_{00} = 38^\circ \pm 25^\circ; |\eta_{00}|/(|f-\bar{f}|/k) = (1.13 \pm 0.12) \cdot 10^{-3}$$

The fit is very stable when the selection criteria are varied, the maximum changes being 10% for the phase, and 6% for $|\eta_{00}|$.

These results are in good agreement with our previous measurement¹⁾ and the average gives

$$\varphi_{00} = 43^\circ \pm 19^\circ$$

We thank Dr. T.J. Ratcliffe who participated in the early stages of the experiment, Mr. J. Olsfors for his efforts in running the apparatus and Miss M.A. Huber and all the scanners and measurers of CERN, Laboratoire de l'Accélérateur Linéaire and Rutherford Laboratory.

TABLE 1

Contributions to the errors

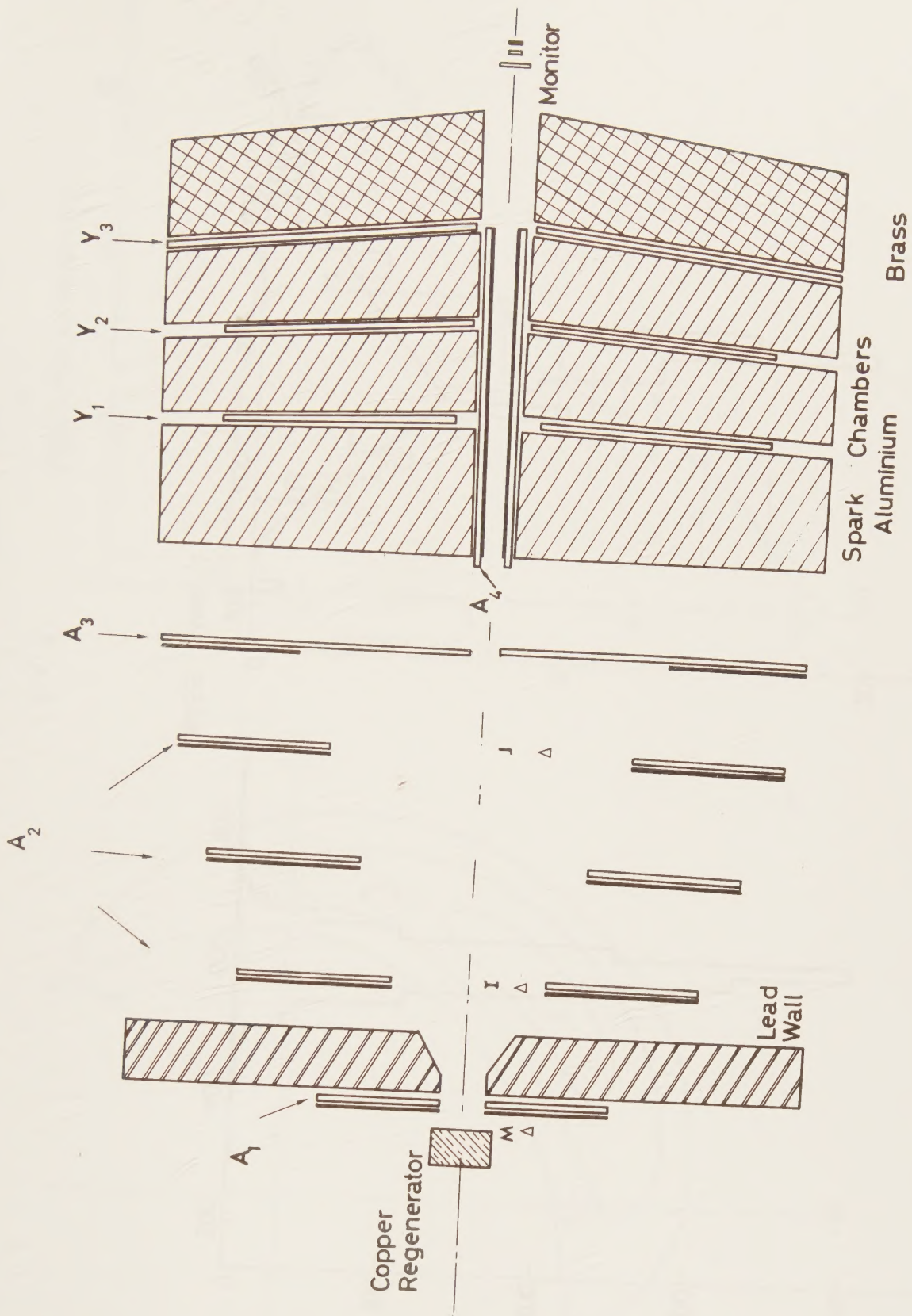
	$ \eta_{00} ^2$	φ_{00}
Statistics	17%	21°
Systematic Vertex shift	/	12°
Efficiency	12%	8°
Background subtraction	10%	/
Monitoring	6%	/

FIGURE CAPTIONS

- Fig. 1 Experimental set up. The four gamma rays are converted in the aluminium chambers (3 radiation lengths spread over 1.05 meter). The brass chambers correspond to 8 radiation lengths. Y_1 , Y_2 and Y_3 are trigger counters. The anticoincidence counters A_1 , A_2 , A_3 , A_4 veto charged decays and $3\pi^0$.
- Fig. 2 a) Mass distribution of regenerator events (position M)
b) Mass distribution of free decay events
The solid curves show the Monte Carlo predicted background.
- Fig. 3 a) Main Regenerator data and best fit for decay time distribution of $K^0 \rightarrow 2\pi^0$ events
b) Likelihood contours for $\eta_{\infty} / (|f - \bar{f}|/k)$ in the complex plane. The center corresponds to the fit shown in Figure 3a.

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The agreement between the results is poor. Two new experiments are under way at Princeton and at CERN.
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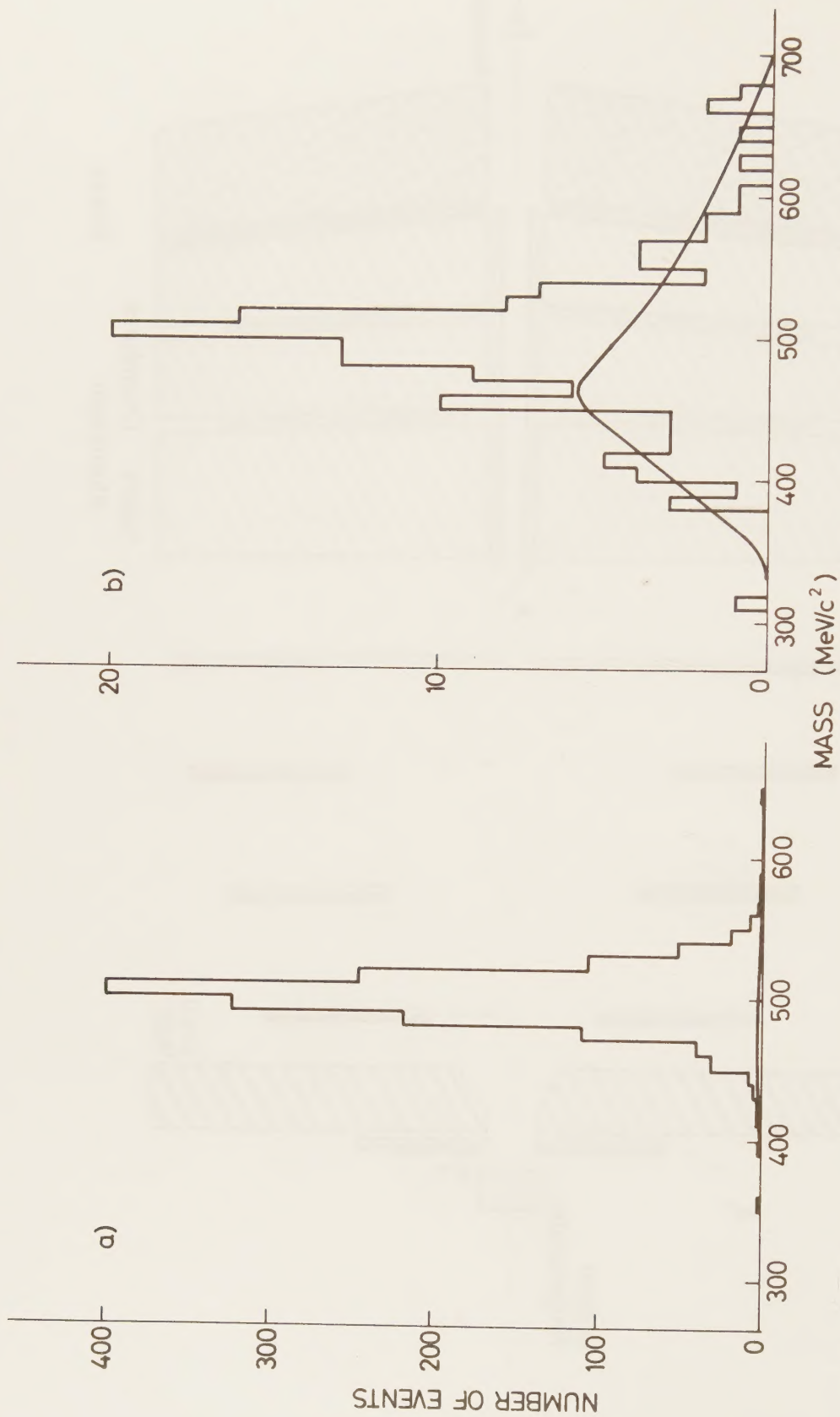


Fig. 2

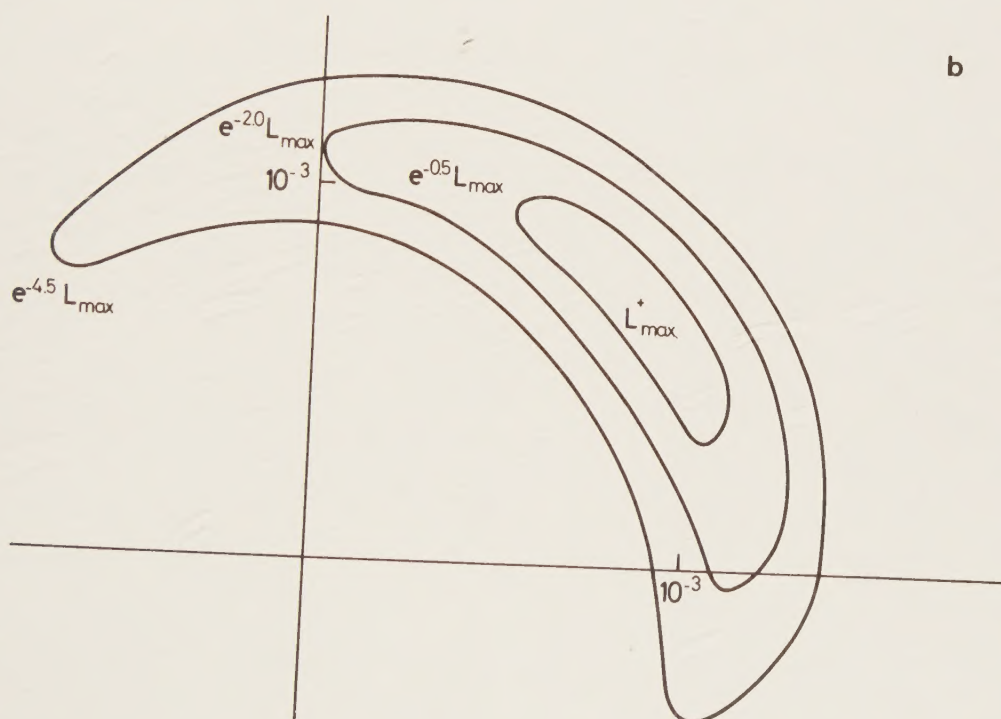
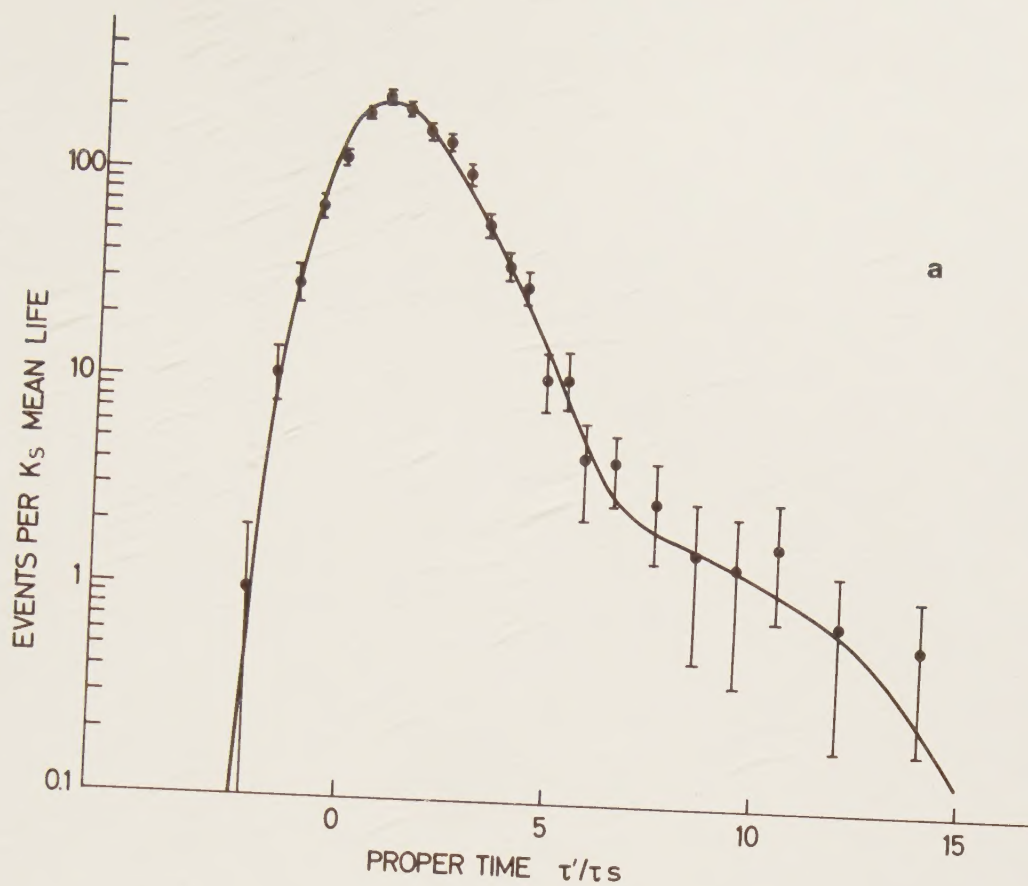


Fig. 3

